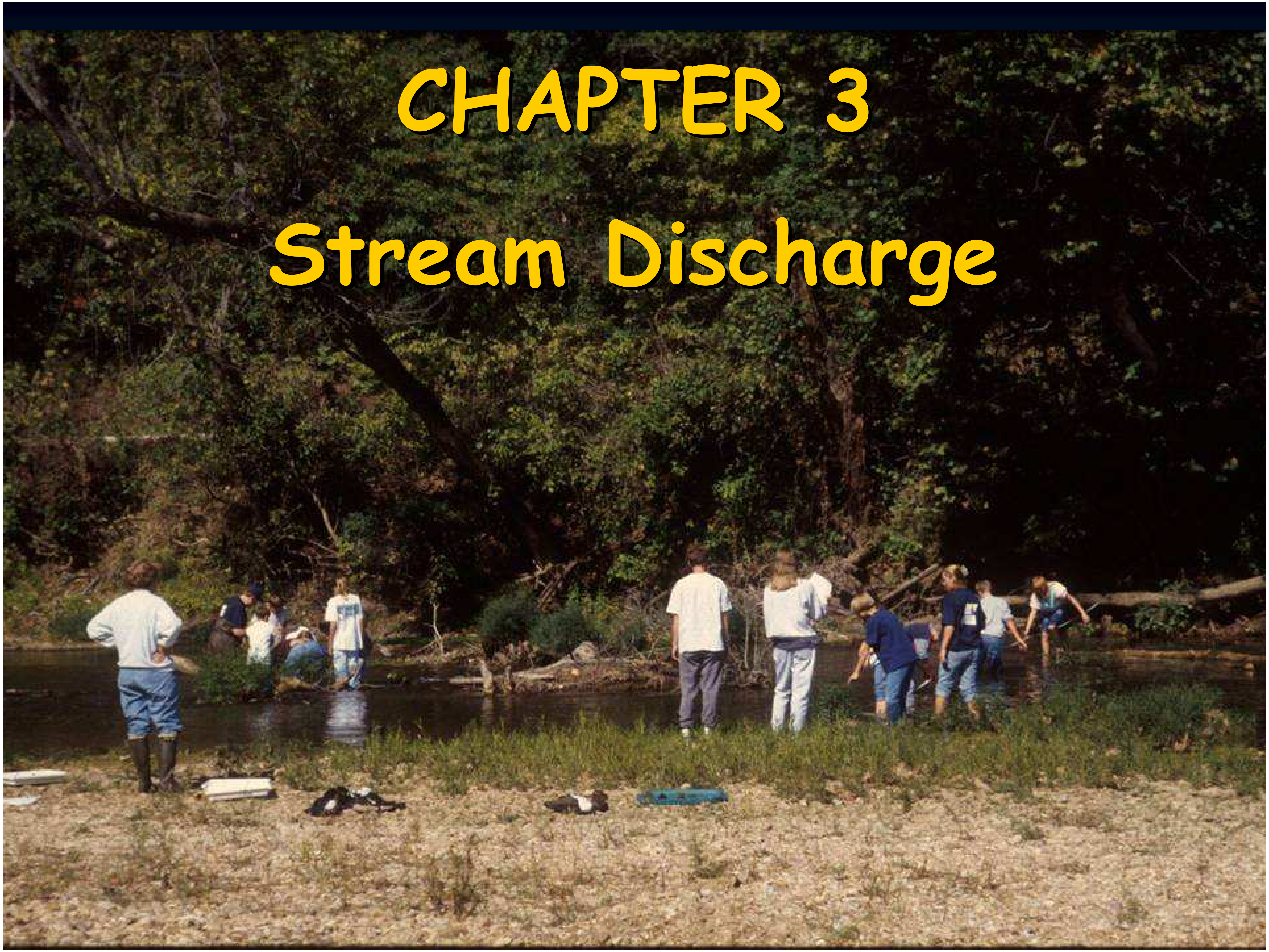
CHAPTER 3

Stream Discharge



Introduction

- Water is a multi-use resource
- In many areas water quality depends on treating human and industrial wastewater
- Requires a natural flow of clean water
- Wastewater loads are determined by flow and assimilation factor
- Increased demand on water and decrease in flows impact water quality

What is Discharge (Flow)?

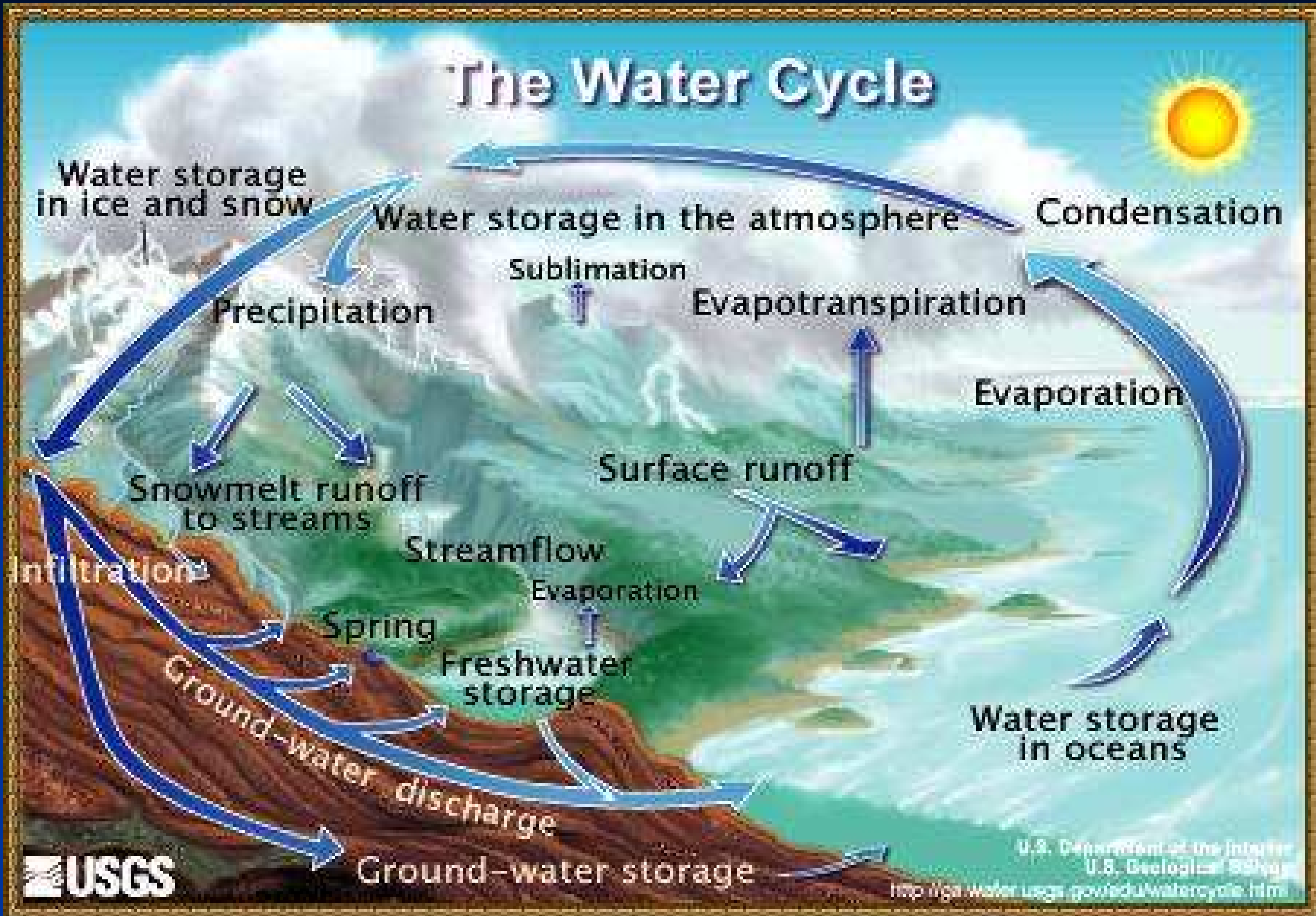
- The volume of water flowing past a given point in a given period of time

- A product of:
  - Cross-Sectional Area (ft^2)
  - Velocity (ft/sec)

- Expressed as:
  - Cubic Feet/Second (cfs)

Why is Stream Discharge Important?

- Important factor influencing water chemistry
- Allows us to quantify and/or extrapolate your information to the whole stream volume
- Gives us an idea of how severe a problem may be



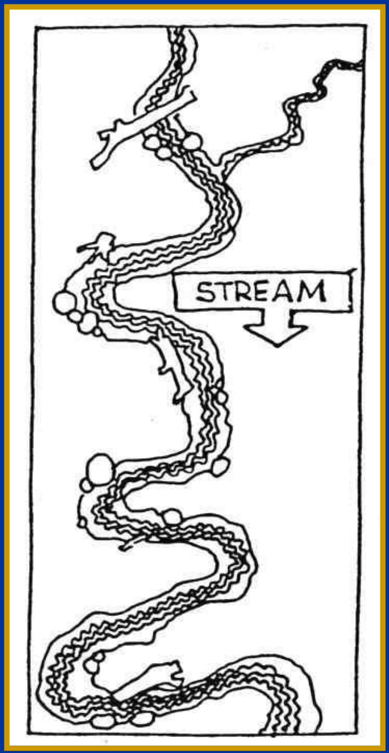
The Water Cycle
Water storage in ice and snow
Water storage in the atmosphere
Condensation
Sublimation
Precipitation
Evapotranspiration
Evaporation
Surface runoff
Snowmelt runoff to streams
Streamflow
Infiltration
Evaporation
Spring
Freshwater storage
Water storage in oceans
Ground-water discharge
Ground-water storage
USGS

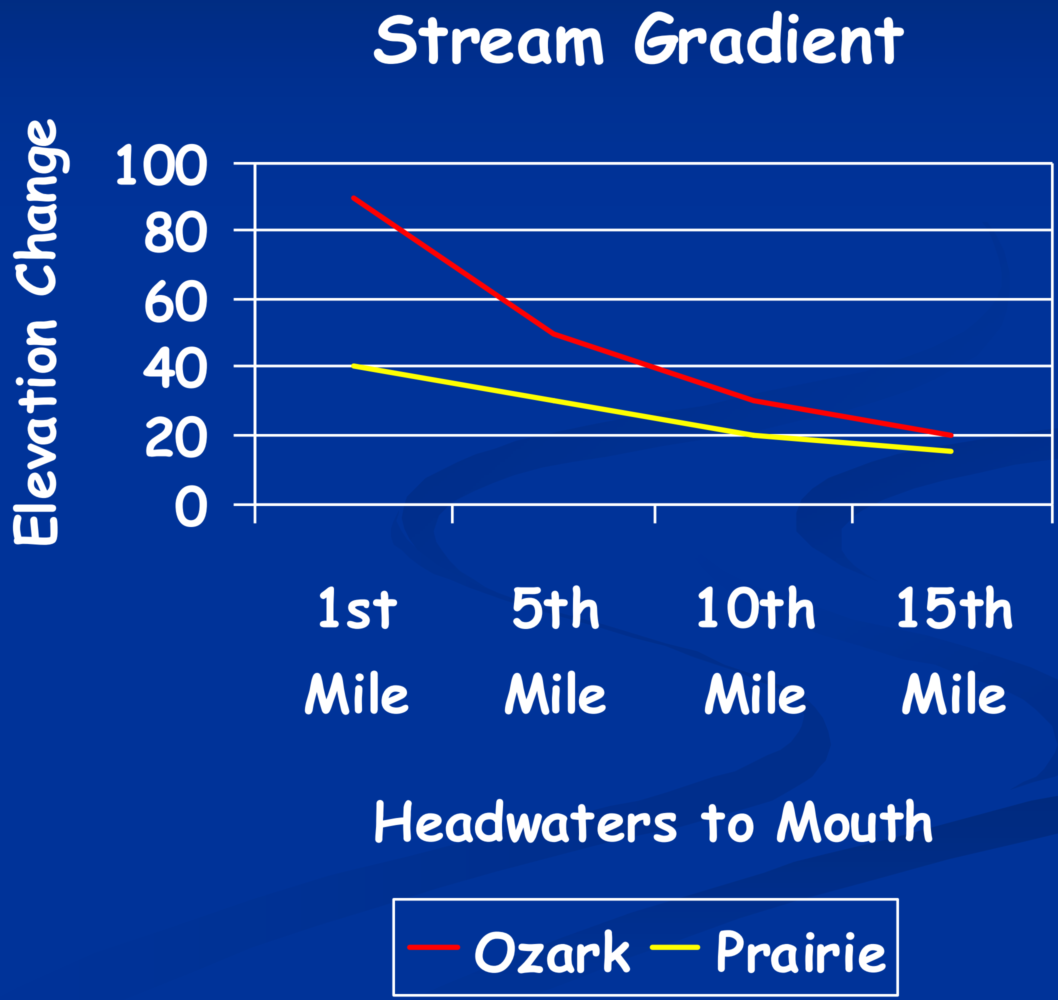
Factors Affecting Volume of Flow

- Precipitation
- Base Flow
- Vegetation
- Other Factors
  - Shallow Groundwater
  - Springs
  - Adjacent Wetlands
  - Tributaries

Factors Affecting Velocity of Flow

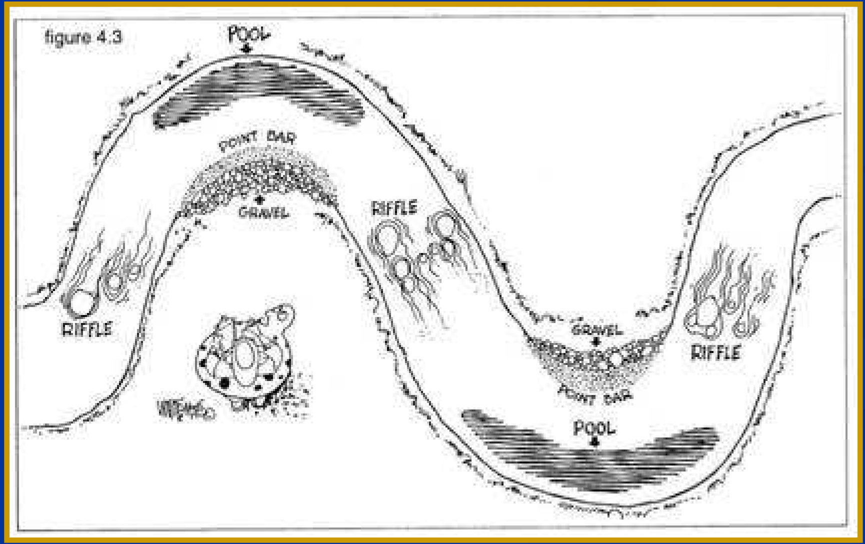
- Volume
- Gradient
- Resistance



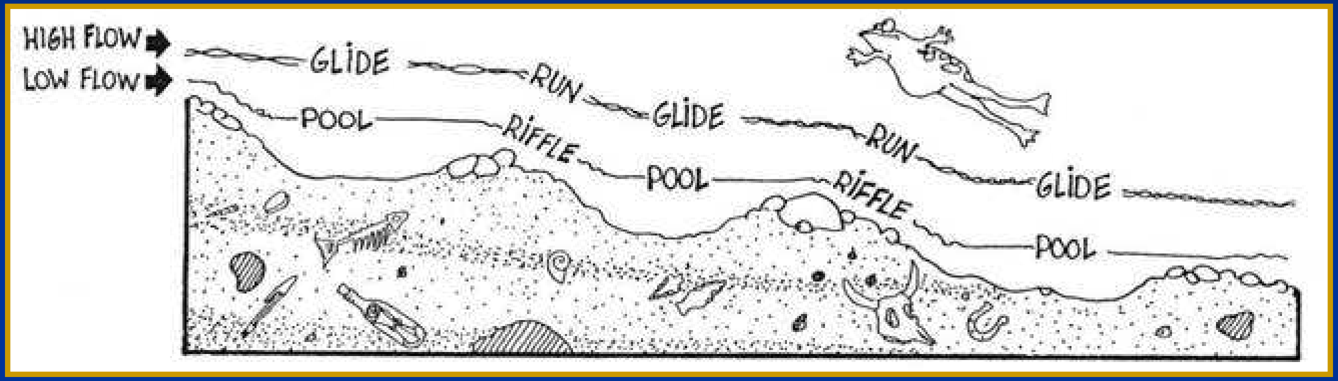


How Flow Affects a Stream

- Concentrations
- Oxygen and Temperature
- Physical Features
  - Shape of the channel and composition of stream bottom



How Flow Affects a Stream



- Flow can determine whether an area is defined as a run, riffle, glide, or pool
- Streams with a variety of velocities can support a more diverse aquatic community

How Flow Affects a Stream

- Concentrations
- Oxygen and Temperature
- Physical Features
- Transport

How Flow Affects a Stream

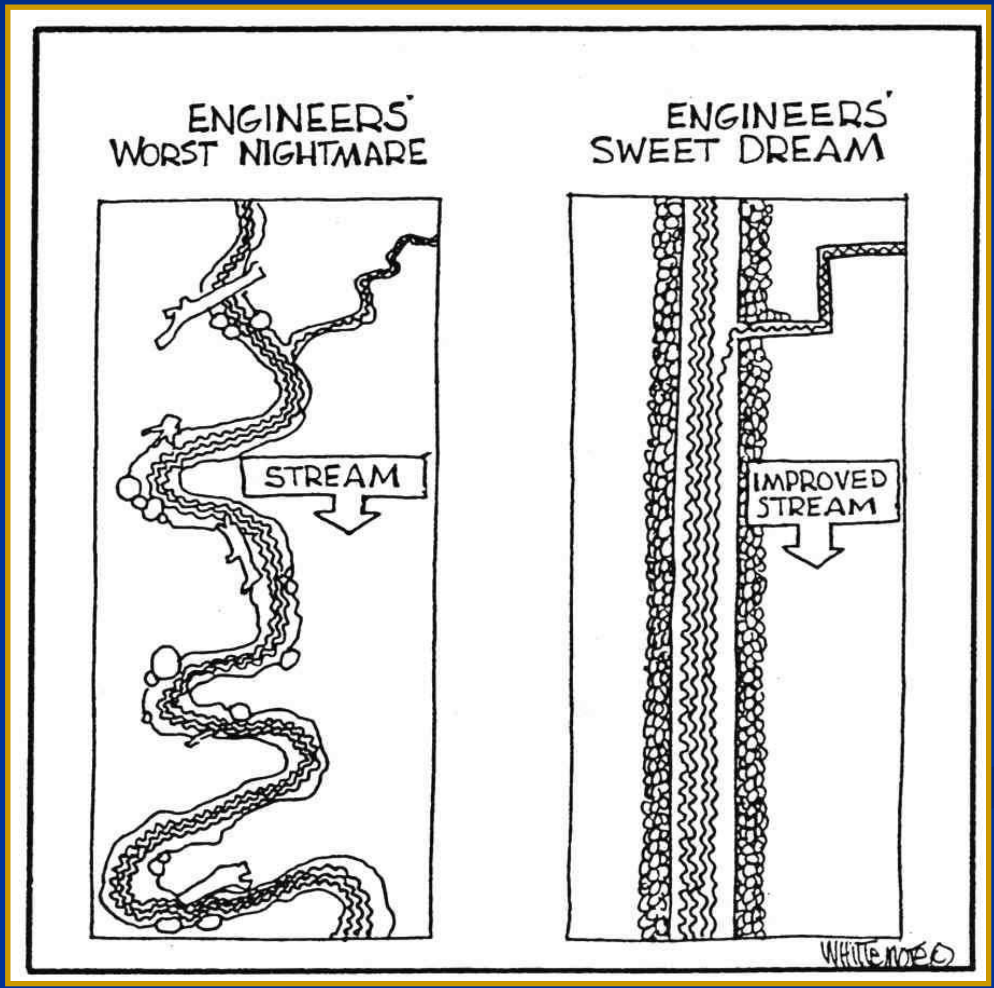
- Concentrations
- Oxygen and Temperature
- Physical Features
- Transport
- Plants and Animals

How Flow Affects a Stream

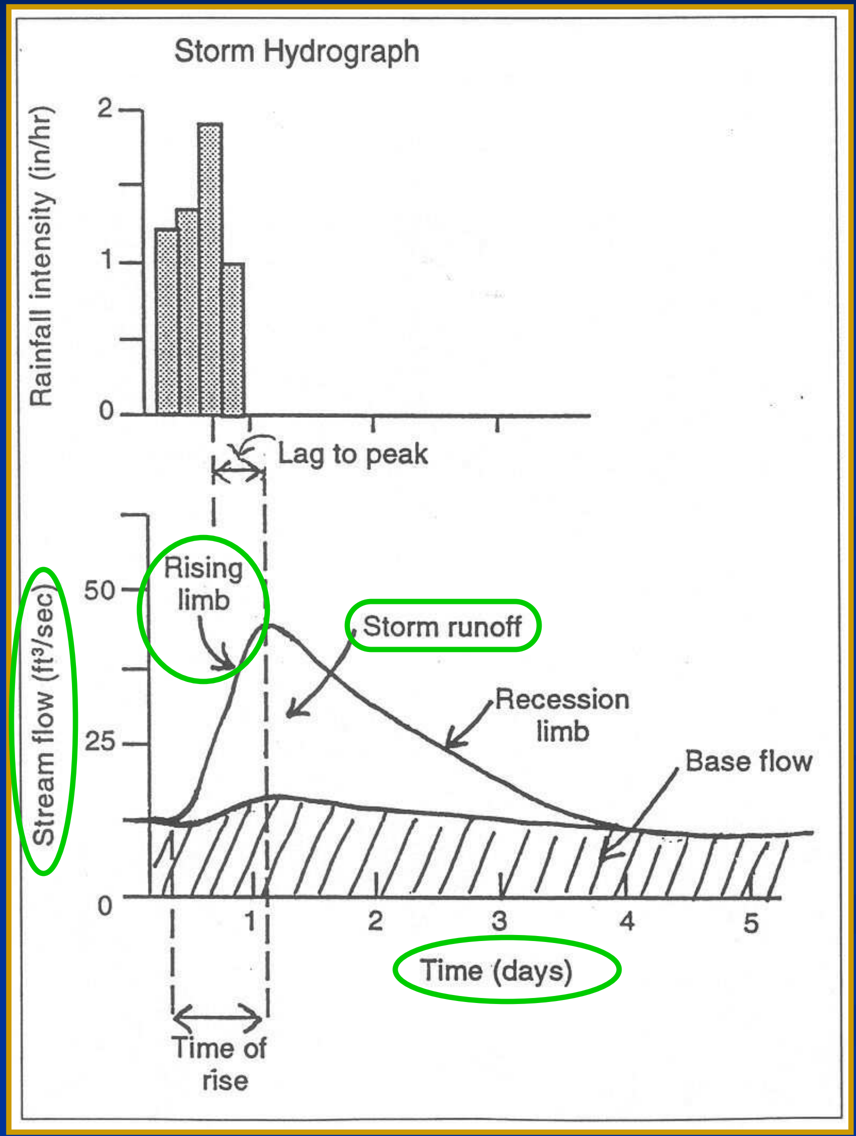
- Concentrations
- Oxygen and Temperature
- Physical Features
- Transport
- Plants and Animals
- Biological cues
- Minimum Instream Flow

How Human Activities Affect Flow

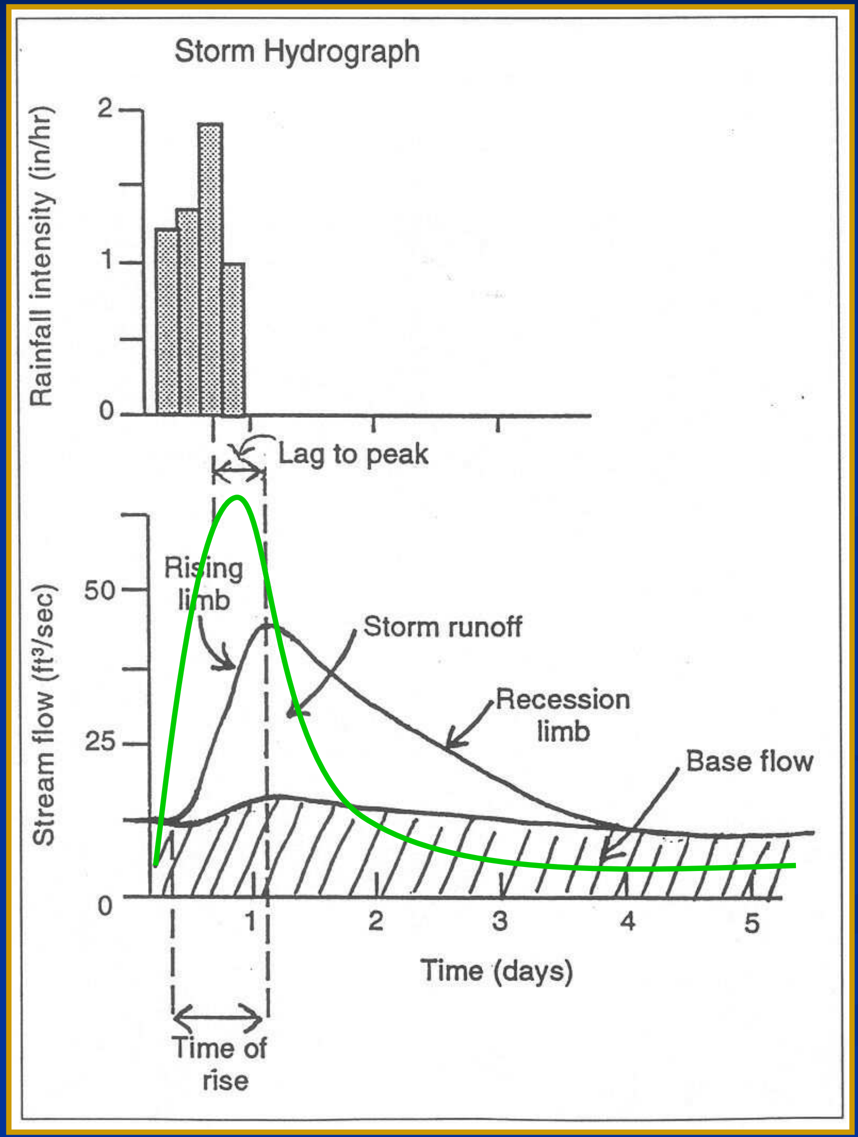
- Land Use
- Channelization
- Dams



Storm Hydrograph



Storm Hydrograph



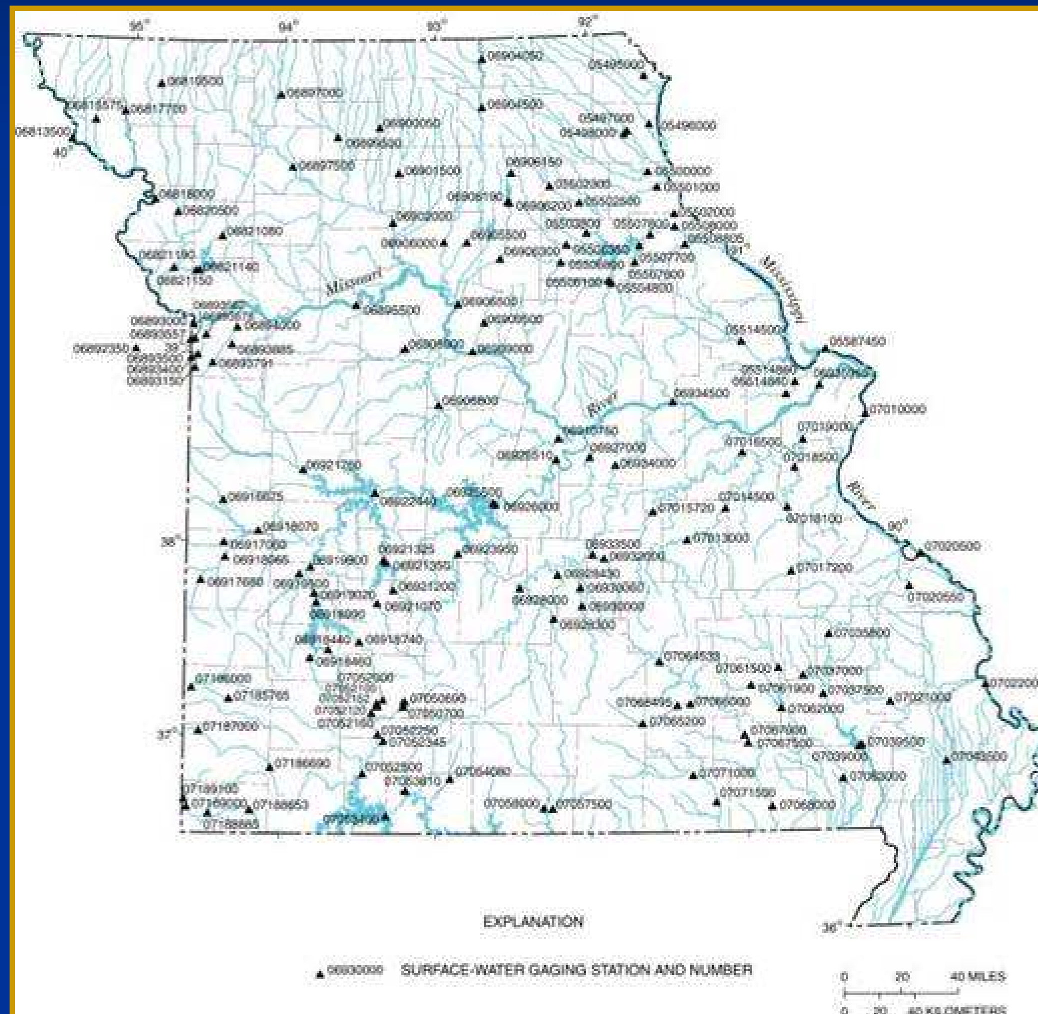
Range of Flows (cfs) on Selected Streams

(Source: USGS, 2008)

Elk Fork of Salt (Madison, MO)	0.06 - 4250
Little Piney River (Newburg, MO)	35 - 789
Gasconade River (Rich Fountain, MO)	403 – 20,800
Missouri River (Hermann, MO)	16,200 – 268,000
Mississippi River (St. Louis, MO)	32,600 – 405,000

USGS Gauging Stations

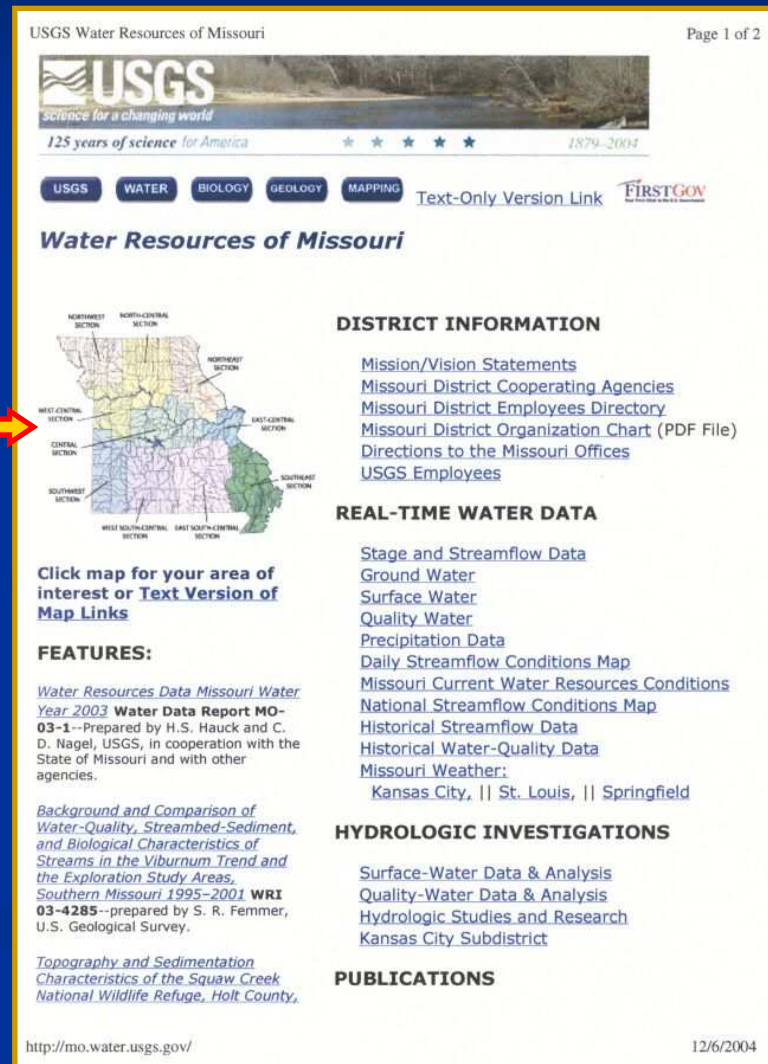
- Nearly 100 gauging stations across Missouri



USGS Water Resources of MO

Clickable Map

- http://mo.water.usgs.gov/
- "Real-Time" format
- Clickable map



USGS Water Resources of Missouri — Page 1 of 2

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125 years of science for America 1879–2004

USGS | WATER | BIOLOGY | GEOLOGY | MAPPING | Text-Only Version Link | FIRSTGOV

Water Resources of Missouri

Click map for your area of interest or Text Version of Map Links

FEATURES:

Water Resources Data Missouri Water Year 2003 **Water Data Report MO-03-1**--Prepared by H.S. Hauck and C. D. Nagel, USGS, in cooperation with the State of Missouri and with other agencies.

Background and Comparison of Water-Quality, Streambed-Sediment, and Biological Characteristics of Streams in the Viburnum Trend and the Exploration Study Areas, Southern Missouri 1995–2001 **WRI 03-4285**--prepared by S. R. Femmer, U.S. Geological Survey.

Topography and Sedimentation Characteristics of the Squaw Creek National Wildlife Refuge, Holt County,

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- Mission/Vision Statements
- Missouri District Cooperating Agencies
- Missouri District Employees Directory
- Missouri District Organization Chart (PDF File)
- Directions to the Missouri Offices
- USGS Employees

REAL-TIME WATER DATA

- Stage and Streamflow Data
- Ground Water
- Surface Water
- Quality Water
- Precipitation Data
- Daily Streamflow Conditions Map
- Missouri Current Water Resources Conditions
- National Streamflow Conditions Map
- Historical Streamflow Data
- Historical Water-Quality Data
- Missouri Weather:
  Kansas City, || St. Louis, || Springfield

HYDROLOGIC INVESTIGATIONS

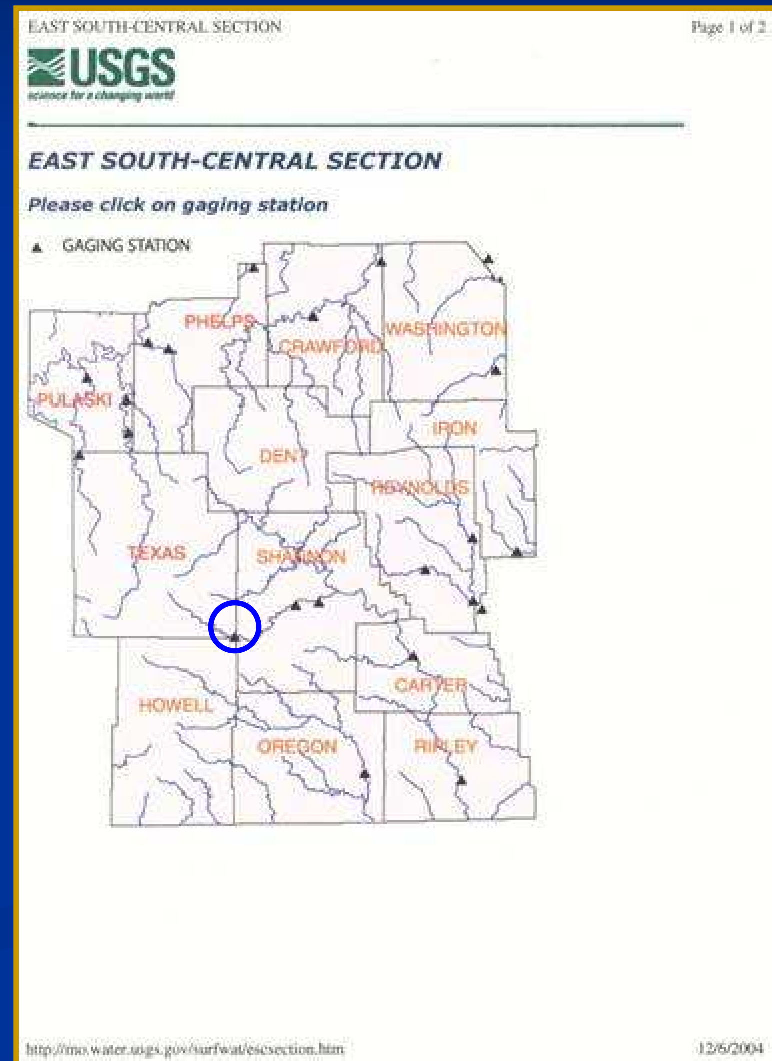
- Surface-Water Data & Analysis
- Quality-Water Data & Analysis
- Hydrologic Studies and Research
- Kansas City Subdistrict

PUBLICATIONS

http://mo.water.usgs.gov/ 12/6/2004

Real-Time Data for MO:
East South-Central Section

- Stations grouped by:
  - County
- Station 07065200
  - Jacks Fork near Mountain View, MO



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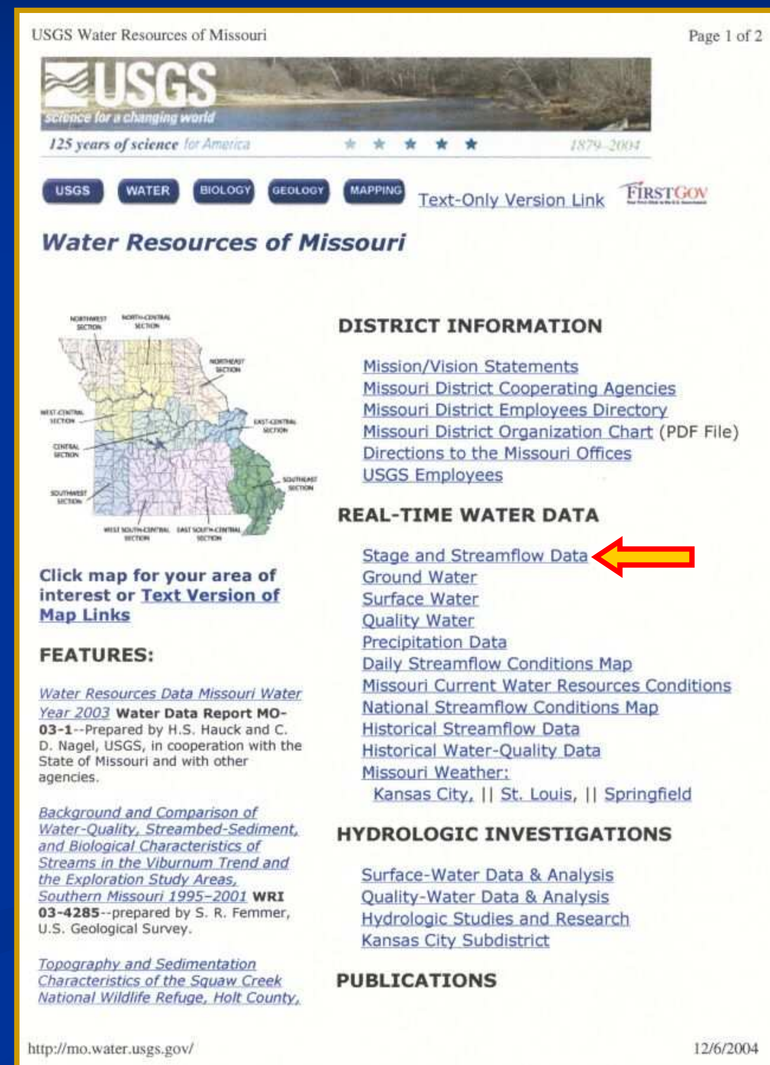
USGS Water Resources of Missouri Page 1 of 2

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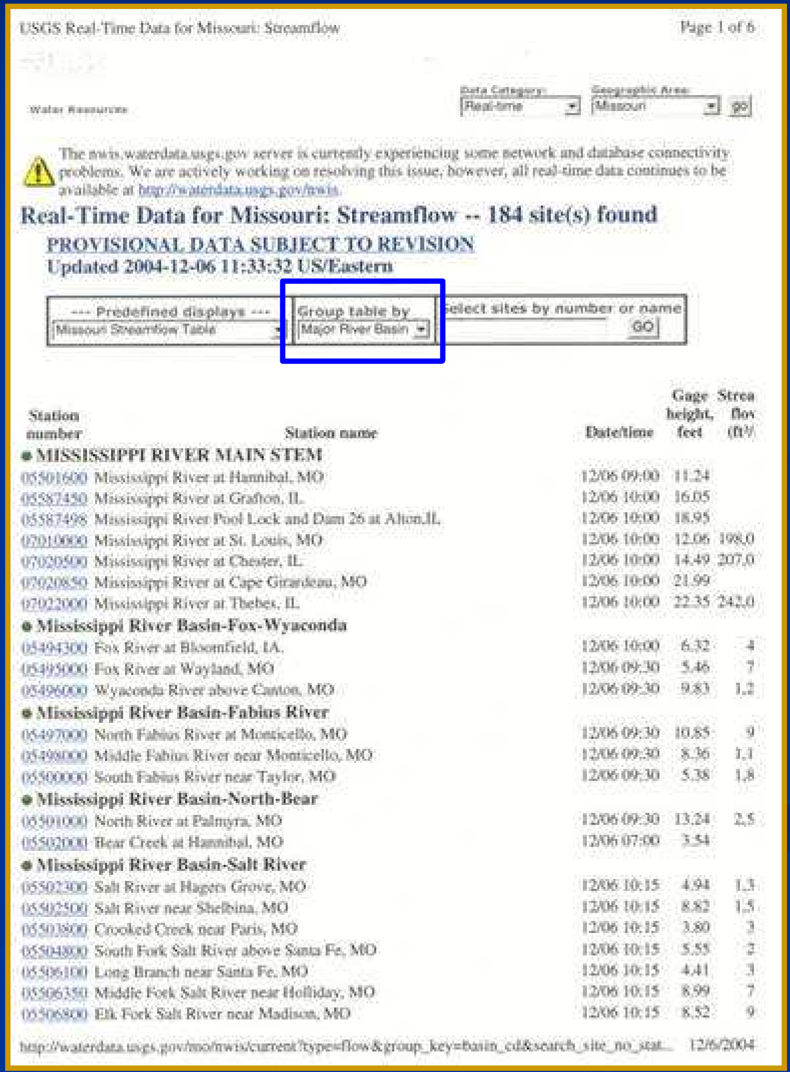
Streamflow

- Stations grouped by:
  - River basin
  - County
  - Hydrological Unit


USGS Real-Time Data for Missouri: Streamflow   Page 1 of 6

Water Resources

Data Category: Real-time   Geographic Area: Missouri   go

The nwis.waterdata.usgs.gov server is currently experiencing some network and database connectivity problems. We are actively working on resolving this issue, however, all real-time data continues to be available at http://waterdata.usgs.gov/nwis.

Real-Time Data for Missouri: Streamflow -- 184 site(s) found

PROVISIONAL DATA SUBJECT TO REVISION
Updated 2004-12-06 11:33:32 US/Eastern

--- Predefined displays --- Missouri Streamflow Table | Group table by Major River Basin | Select sites by number or name GO

Station number	Station name	Date/time	Gage height, feet	Strea flov (ft³/
MISSISSIPPI RIVER MAIN STEM				
05501600	Mississippi River at Hannibal, MO	12/06 09:00	11.24	
05587450	Mississippi River at Grafton, IL	12/06 10:00	16.05	
05587498	Mississippi River Pool Lock and Dam 26 at Alton,IL	12/06 10:00	18.95	
07010000	Mississippi River at St. Louis, MO	12/06 10:00	12.06	198,0
07020500	Mississippi River at Chester, IL	12/06 10:00	14.49	207,0
07020850	Mississippi River at Cape Girardeau, MO	12/06 10:00	21.99	
07022000	Mississippi River at Thebes, IL	12/06 10:00	22.35	242,0
Mississippi River Basin-Fox-Wyaconda				
05494300	Fox River at Bloomfield, IA.	12/06 10:00	6.32	4
05495000	Fox River at Wayland, MO	12/06 09:30	5.46	7
05496000	Wyaconda River above Canton, MO	12/06 09:30	9.83	1,2
Mississippi River Basin-Fabius River				
05497000	North Fabius River at Monticello, MO	12/06 09:30	10.85	9
05498000	Middle Fabius River near Monticello, MO	12/06 09:30	8.36	1,1
05500000	South Fabius River near Taylor, MO	12/06 09:30	5.38	1,8
Mississippi River Basin-North-Bear				
05501000	North River at Palmyra, MO	12/06 09:30	13.24	2,5
05502000	Bear Creek at Hannibal, MO	12/06 07:00	3.54	
Mississippi River Basin-Salt River				
05502300	Salt River at Hagers Grove, MO	12/06 10:15	4.94	1,3
05502500	Salt River near Shelbina, MO	12/06 10:15	8.82	1,5
05503800	Crooked Creek near Paris, MO	12/06 10:15	3.80	3
05504800	South Fork Salt River above Santa Fe, MO	12/06 10:15	5.55	2
05506100	Long Branch near Santa Fe, MO	12/06 10:15	4.41	3
05506350	Middle Fork Salt River near Holliday, MO	12/06 10:15	8.99	7
05506800	Elk Fork Salt River near Madison, MO	12/06 10:15	8.52	9

http://waterdata.usgs.gov/mo/nwis/current?type=flow&group_key=basin_cd&search_site_no_stat...   12/6/2004

Real-Time Data for MO:
Streamflow

- Stations grouped by:
  - River basin
  - County
  - Hydrological Unit
- Station 07065200
  - Jacks Fork River near Mountain View, MO

USGS Real-Time Data for Missouri: Streamflow — Page 5 of 6

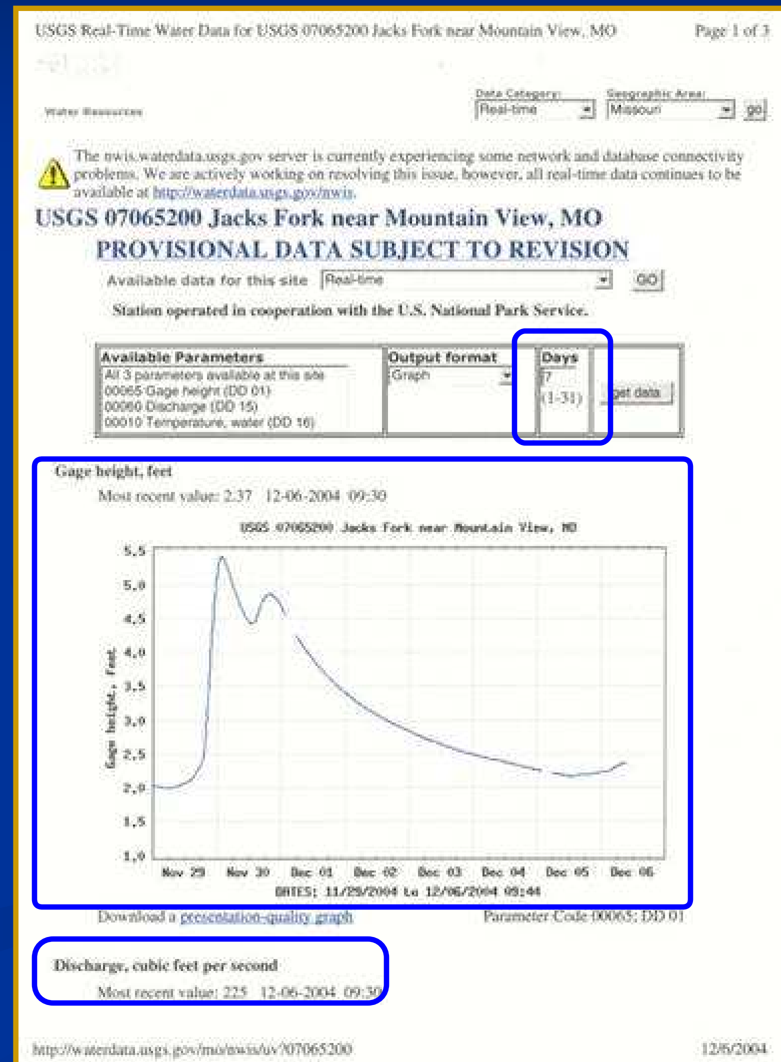
Mississippi River Basin-Castor River				
07021000	Castor River at Zalma, MO	12/06 08:45	5.83	
		12/06 00:00	–	8
Mississippi River Basin-St. Francis River				
07034000	St. Francis River near Roselle, MO	12/06 09:15	3.81	
07035000	Little St. Francis River at Fredericktown, MO	12/06 09:15	4.06	
07035800	St. Francis River near Mill Creek, MO	12/06 09:15	4.06	8
07036100	St. Francis River near Saco, MO	12/06 09:15	4.89	
07037500	St. Francis River near Patterson, MO	12/06 09:30	7.75	1,7
07039500	St. Francis River at Wappapello, MO	12/06 09:00	19.04	3,8
07040000	St. Francis River at Fisk, MO	12/06 06:00	10.77	3,6
07043500	Little River Ditch No. 1 near Morehouse, MO	12/06 07:41	4.44	7
Mississippi River Basin-White River				
07050690	Pearson Creek near Springfield, MO	12/06 07:30	3.16	
07050700	James River near Springfield, MO	12/06 07:45	5.41	3
07052000	Wilson Creek at Springfield, MO	12/06 09:45	3.13	
07052100	Wilson Creek near Springfield, MO	12/06 10:00	1.92	
07052160	Wilson Creek nr Battlefield MO	12/06 09:45	2.95	1
07052250	James River near Boaz, MO	12/06 09:45	4.00	8
07052345	Finley Creek below Riverdale, MO	12/06 09:45	2.47	4
07052500	James River at Galena, MO	12/06 07:00	5.67	1,9
07053400	Table Rock Lake near Branson, MO	12/06 08:00	10.71	
07053810	Bull Creek near Walnut Shade, MO	12/06 08:00	4.26	
07054080	Beaver Creek at Bradleyville, MO	12/06 07:15	3.75	
07057500	North Fork River near Tecumseh, MO	12/06 07:00	3.30	9
07058000	Bryant Creek near Tecumseh, MO	12/06 08:15	5.03	
07061270	East Fork Black River nr Lesterville, MO	12/06 06:30	1.27	
07061500	Black River near Annapolis, MO	12/06 07:00	4.51	6
07061900	Logan Creek at Ellington, MO	12/06 07:00	2.13	
07062050	Clearwater Tailwater near Piedmont, MO	12/06 08:00	55.70	
07063000	Black River at Poplar Bluff, MO	12/06 08:30	8.57	3,3
07064533	Current River above Akers, MO	12/05 15:35	1.79	4
07065200	Jacks Fork near Mountain View, MO	12/06 09:30	2.37	2
07065495	Jacks Fork at Alley Spring, MO	12/06 09:30	2.86	2
07066000	Jacks Fork at Eminence, MO	12/06 09:30	3.25	6
07067000	Current River at Van Buren, MO	12/06 07:00	3.18	2,6
07068000	Current River at Doniphan, MO	12/06 07:15	2.19	3,6
07071500	Eleven Point River near Bardley, MO	12/06 10:15	2.83	8
Mississippi River Basin-Arkansas River				
07185765	Spring River at Carthage, MO	12/06 09:45	4.68	9
07186000	Spring River near Waco, MO	12/06 08:15	7.22	
07187000	Shoal Creek above Joplin, MO	12/06 08:15	3.56	7
07188653	Big Sugar Creek near Powell, MO	12/06 09:25	3.69	1
07188838	Little Sugar Creek near Pineville, MO	12/06 09:25	4.35	
07188885	Indian Creek near Lanagan, MO	12/06 09:25	2.72	3

http://waterdata.usgs.gov/mo/nwis/current?type=flow&group_key=basin_cd&search_site_no_stat... 12/6/2004

Jacks Fork near Mountain View

Station 07065200

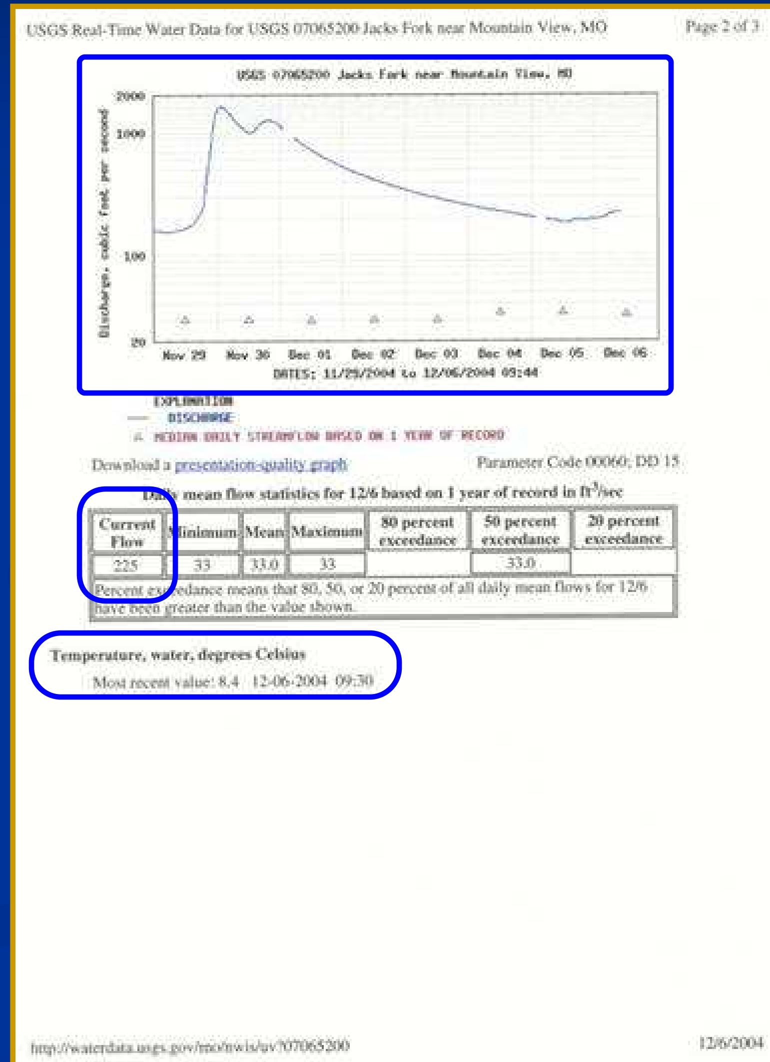
- Gage Height
- Current Flow
- Historical Data



Jacks Fork near Mountain View

Station 07065200

- Hydrograph
- Current Flow
- Water Temperature



Download a presentation-quality graph Parameter Code 00060; DD 15

Daily mean flow statistics for 12/6 based on 1 year of record in ft^3/sec

Current Flow	Minimum	Mean	Maximum	80 percent exceedance	50 percent exceedance	20 percent exceedance
225	33	33.0	33		33.0	

Percent exceedance means that 80, 50, or 20 percent of all daily mean flows for 12/6 have been greater than the value shown.

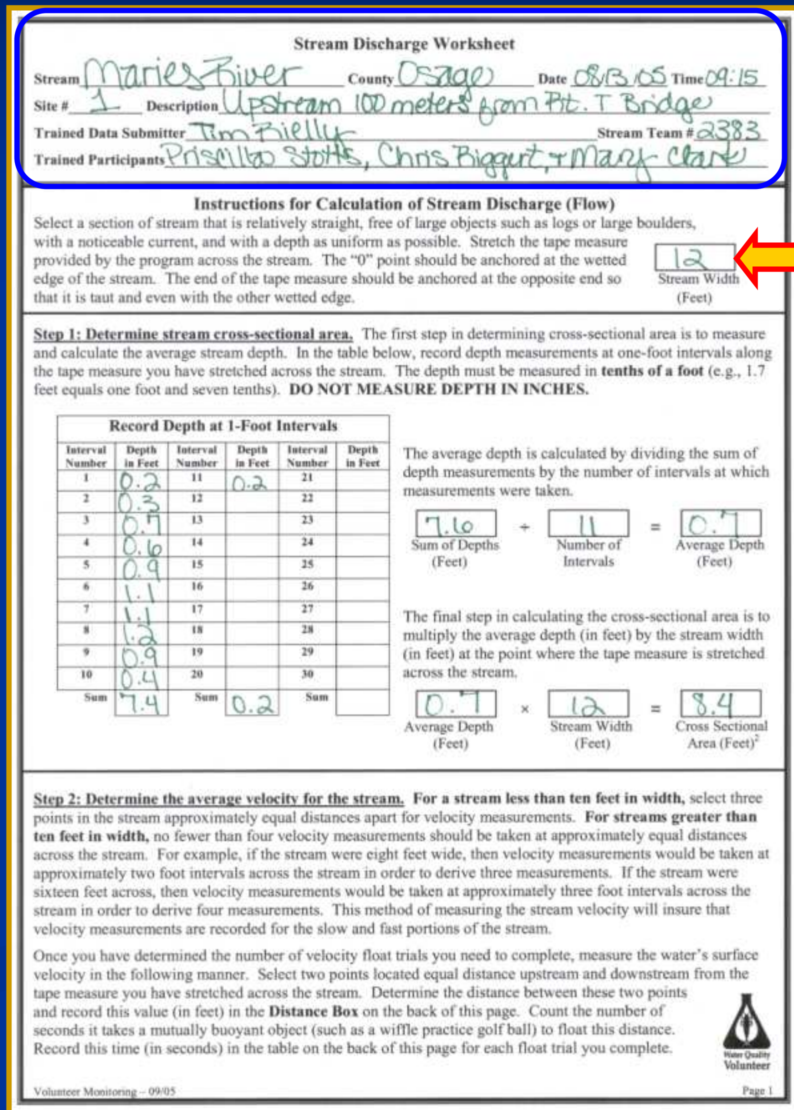
Temperature, water, degrees Celsius

Most recent value: 8.4 12-06-2004 09:30

How to Measure Flow

Stream Discharge Worksheet

- Information at top
- Stream width



Stream Discharge Worksheet

Stream Maries River **County** Osage **Date** 08/13/05 **Time** 09:15
Site # 1 **Description** Upstream 100 meters from Rt. T Bridge
Trained Data Submitter Tim Rielly **Stream Team #** 2383
Trained Participants Priscilla Stotts, Chris Riggert, & Mary Clark

Instructions for Calculation of Stream Discharge (Flow)

Select a section of stream that is relatively straight, free of large objects such as logs or large boulders, with a noticeable current, and with a depth as uniform as possible. Stretch the tape measure provided by the program across the stream. The "0" point should be anchored at the wetted edge of the stream. The end of the tape measure should be anchored at the opposite end so that it is taut and even with the other wetted edge.

12
Stream Width (Feet)

Step 1: Determine stream cross-sectional area. The first step in determining cross-sectional area is to measure and calculate the average stream depth. In the table below, record depth measurements at one-foot intervals along the tape measure you have stretched across the stream. The depth must be measured in **tenths of a foot** (e.g., 1.7 feet equals one foot and seven tenths). **DO NOT MEASURE DEPTH IN INCHES.**

Record Depth at 1-Foot Intervals

Interval Number	Depth in Feet	Interval Number	Depth in Feet	Interval Number	Depth in Feet
1	0.2	11	0.2	21	
2	0.3	12		22	
3	0.7	13		23	
4	0.6	14		24	
5	0.9	15		25	
6	1.1	16		26	
7	1.1	17		27	
8	1.2	18		28	
9	0.9	19		29	
10	0.4	20		30	
Sum	7.4	Sum	0.2	Sum	

The average depth is calculated by dividing the sum of depth measurements by the number of intervals at which measurements were taken.

7.6 Sum of Depths (Feet) ÷ 11 Number of Intervals = 0.7 Average Depth (Feet)

The final step in calculating the cross-sectional area is to multiply the average depth (in feet) by the stream width (in feet) at the point where the tape measure is stretched across the stream.

0.7 Average Depth (Feet) × 12 Stream Width (Feet) = 8.4 Cross Sectional Area $(Feet)^2$

Step 2: Determine the average velocity for the stream. **For a stream less than ten feet in width,** select three points in the stream approximately equal distances apart for velocity measurements. **For streams greater than ten feet in width,** no fewer than four velocity measurements should be taken at approximately equal distances across the stream. For example, if the stream were eight feet wide, then velocity measurements would be taken at approximately two foot intervals across the stream in order to derive three measurements. If the stream were sixteen feet across, then velocity measurements would be taken at approximately three foot intervals across the stream in order to derive four measurements. This method of measuring the stream velocity will insure that velocity measurements are recorded for the slow and fast portions of the stream.

Once you have determined the number of velocity float trials you need to complete, measure the water's surface velocity in the following manner. Select two points located equal distance upstream and downstream from the tape measure you have stretched across the stream. Determine the distance between these two points and record this value (in feet) in the **Distance Box** on the back of this page. Count the number of seconds it takes a mutually buoyant object (such as a wiffle practice golf ball) to float this distance. Record this time (in seconds) in the table on the back of this page for each float trial you complete.

Water Quality Volunteer

Volunteer Monitoring – 09/05 Page 1

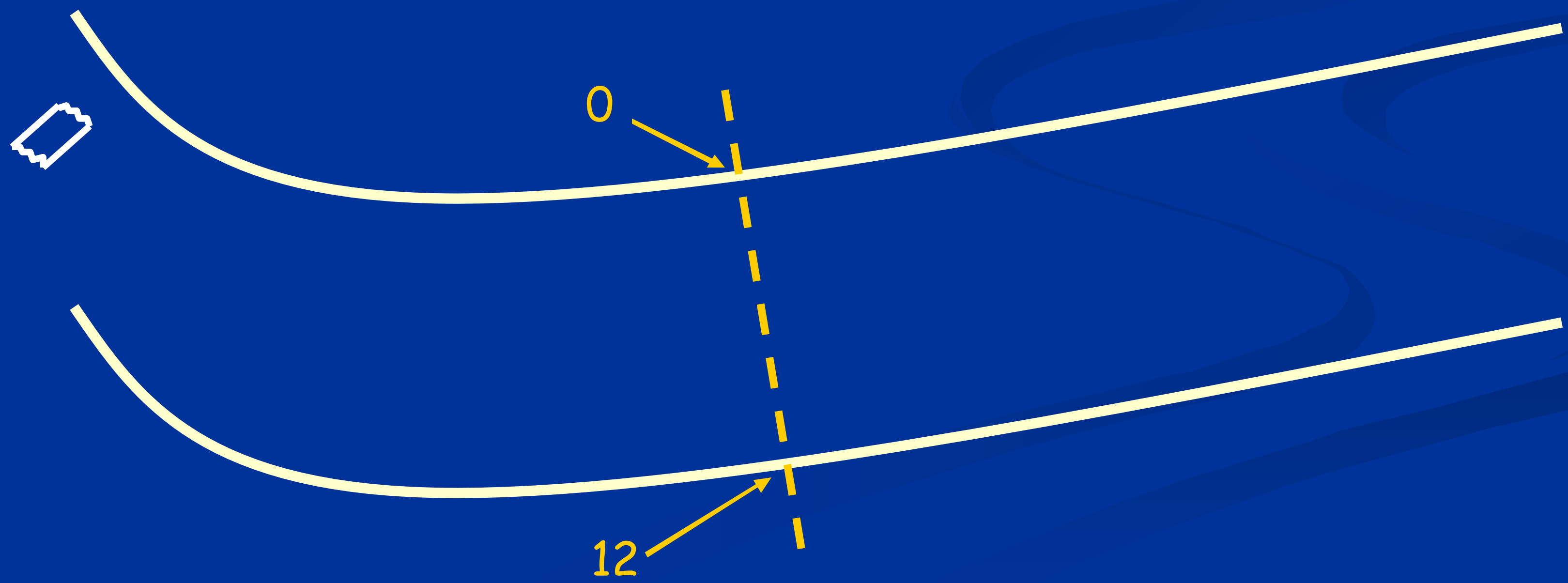
Materials Needed

- A float → the practice, wiffle golf ball (we provide)
- 100-ft. tape measure marked in 10^{ths} of a foot (we provide)
- Two sticks or metal pins
- Stick with depths marked in 10^{ths} of a foot
- Stopwatch or watch with a second hand
- 10-foot-long rope

How to Measure Flow

Step 1 – Surface Width

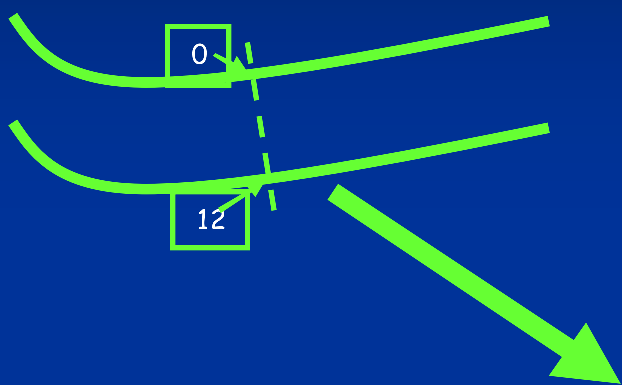
- Measure the width of the flowing portion
  - 10ths of a foot
- DO NOT:
  - Measure "dead" water
  - In inches



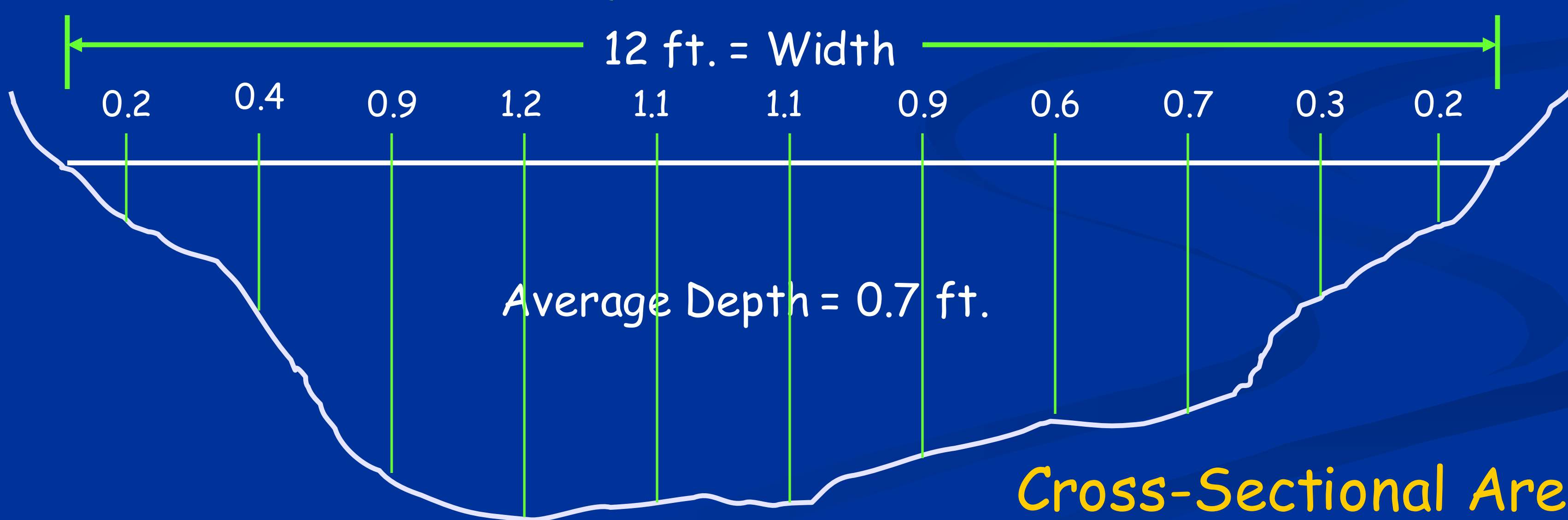
How to Measure Flow

Step 1 – Surface Width

How to Measure Flow
Step 2 – Cross-Sectional Area



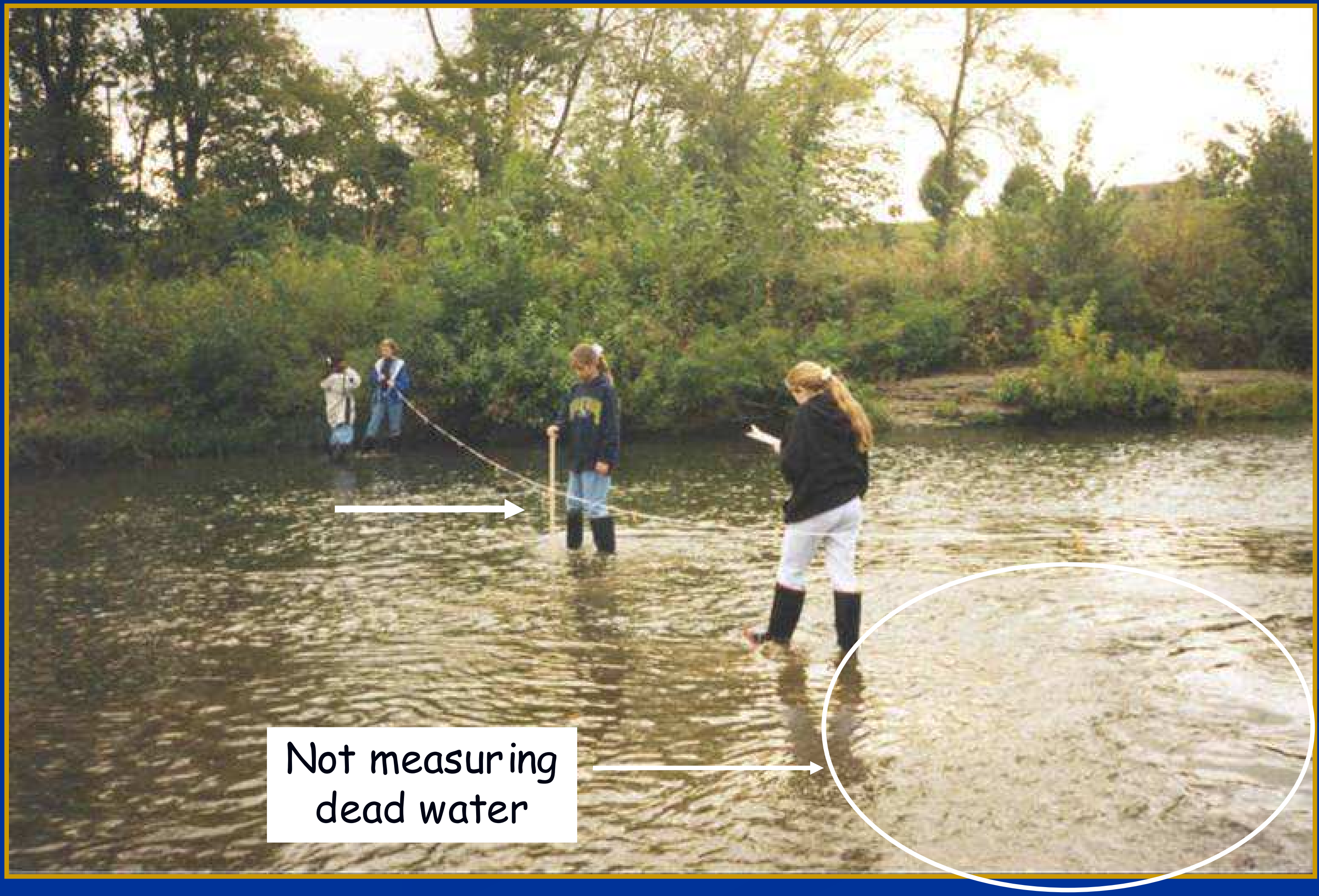
- Measure depths
  - 10ths of a foot
- Stream size:
  - <20 ft. wide = every foot
  - >20 ft. wide = every 2 feet



Cross-Sectional Area =
0.7 x 12 = **8.4 ft.^{2}**

How to Measure Flow

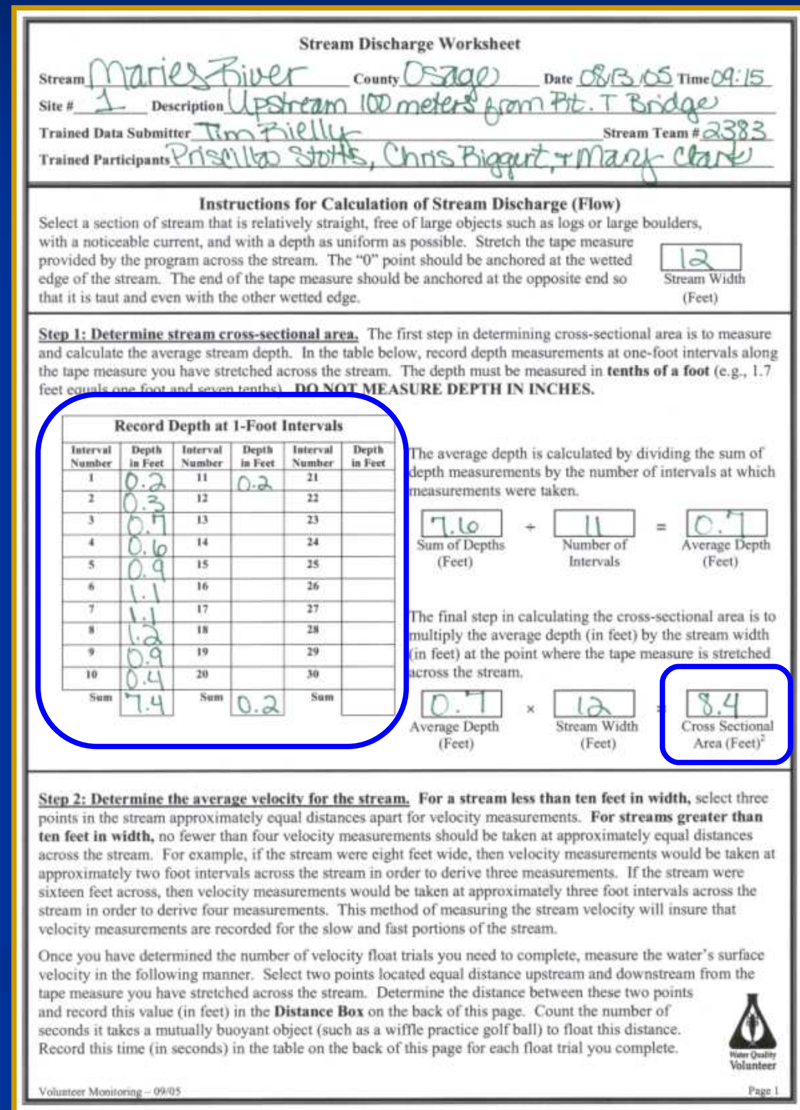
Step 2 – Cross-Sectional Area



How to Measure Flow

Stream Discharge Worksheet

- Header information should match Site ID data sheet
- Must turn these data in with Site ID data sheet
- Stream depths
- Cross-sectional area



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1	0.2	11	0.2	21	
2	0.3	12		22	
3	0.7	13		23	
4	0.6	14		24	
5	0.9	15		25	
6	1.1	16		26	
7	1.1	17		27	
8	1.2	18		28	
9	0.9	19		29	
10	0.4	20		30	
Sum	7.4	Sum	0.2	Sum	

The average depth is calculated by dividing the sum of depth measurements by the number of intervals at which measurements were taken.

7.6 Sum of Depths (Feet) ÷ 11 Number of Intervals = 0.7 Average Depth (Feet)

The final step in calculating the cross-sectional area is to multiply the average depth (in feet) by the stream width (in feet) at the point where the tape measure is stretched across the stream.

0.7 Average Depth (Feet) × 12 Stream Width (Feet) = 8.4 Cross Sectional Area $(Feet)^2$

Step 2: Determine the average velocity for the stream. **For a stream less than ten feet in width,** select three points in the stream approximately equal distances apart for velocity measurements. **For streams greater than ten feet in width,** no fewer than four velocity measurements should be taken at approximately equal distances across the stream. For example, if the stream were eight feet wide, then velocity measurements would be taken at approximately two foot intervals across the stream in order to derive three measurements. If the stream were sixteen feet across, then velocity measurements would be taken at approximately three foot intervals across the stream in order to derive four measurements. This method of measuring the stream velocity will insure that velocity measurements are recorded for the slow and fast portions of the stream.

Once you have determined the number of velocity float trials you need to complete, measure the water's surface velocity in the following manner. Select two points located equal distance upstream and downstream from the tape measure you have stretched across the stream. Determine the distance between these two points and record this value (in feet) in the **Distance Box** on the back of this page. Count the number of seconds it takes a mutually buoyant object (such as a wiffle practice golf ball) to float this distance. Record this time (in seconds) in the table on the back of this page for each float trial you complete.

Water Quality Volunteer

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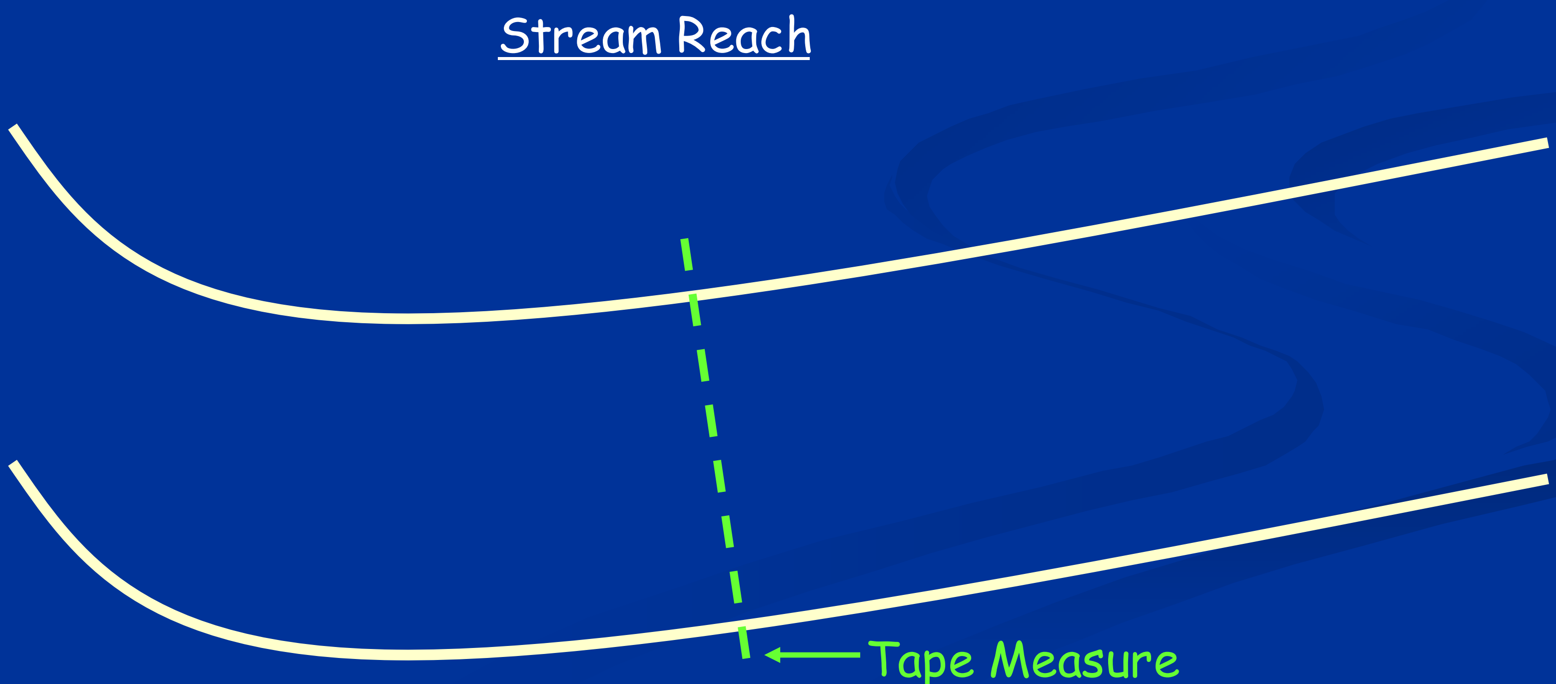
How to Measure Flow
Step 3 – Surface Velocity

- Streams < 10 ft. wide = 3 velocity meas.
- Streams > 10 ft. wide = no fewer than 4 velocity measurements



How to Measure Flow
Step 3 – Surface Velocity

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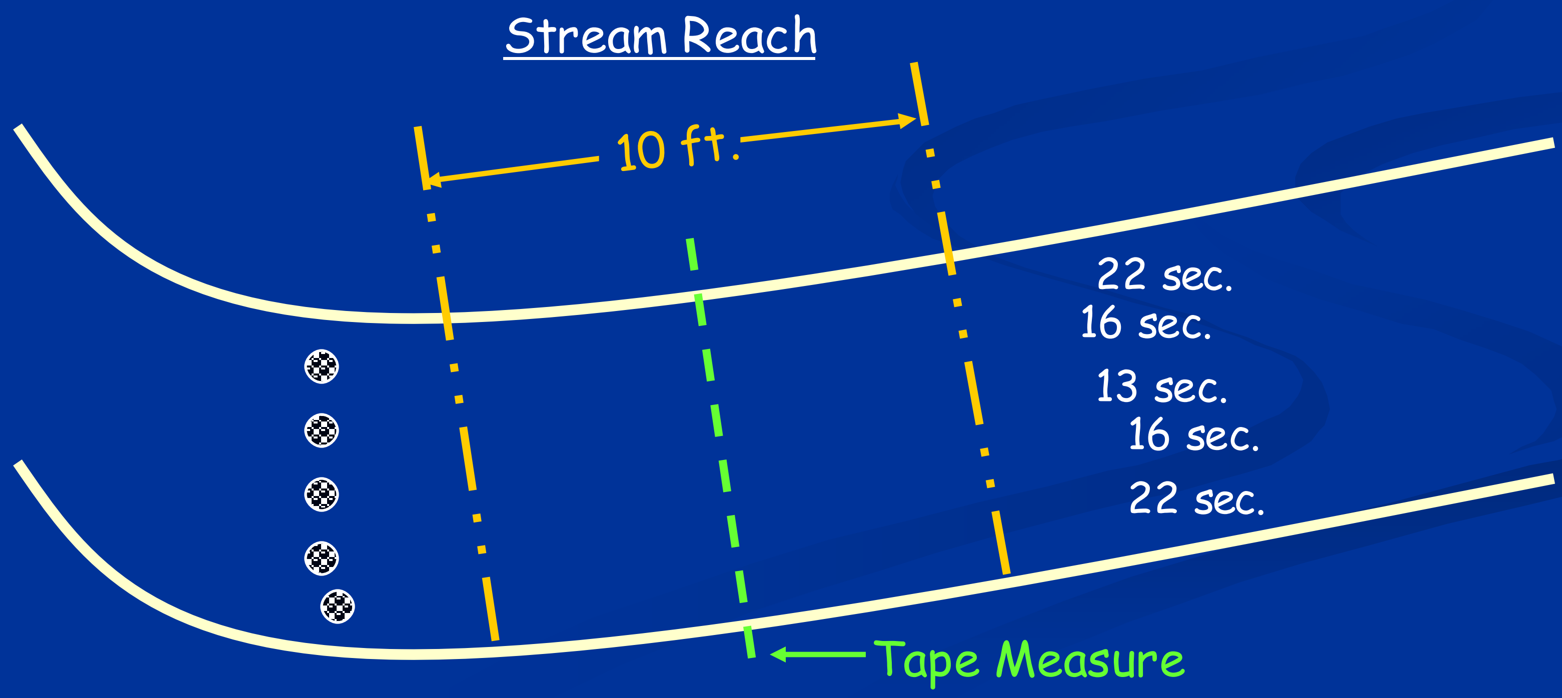
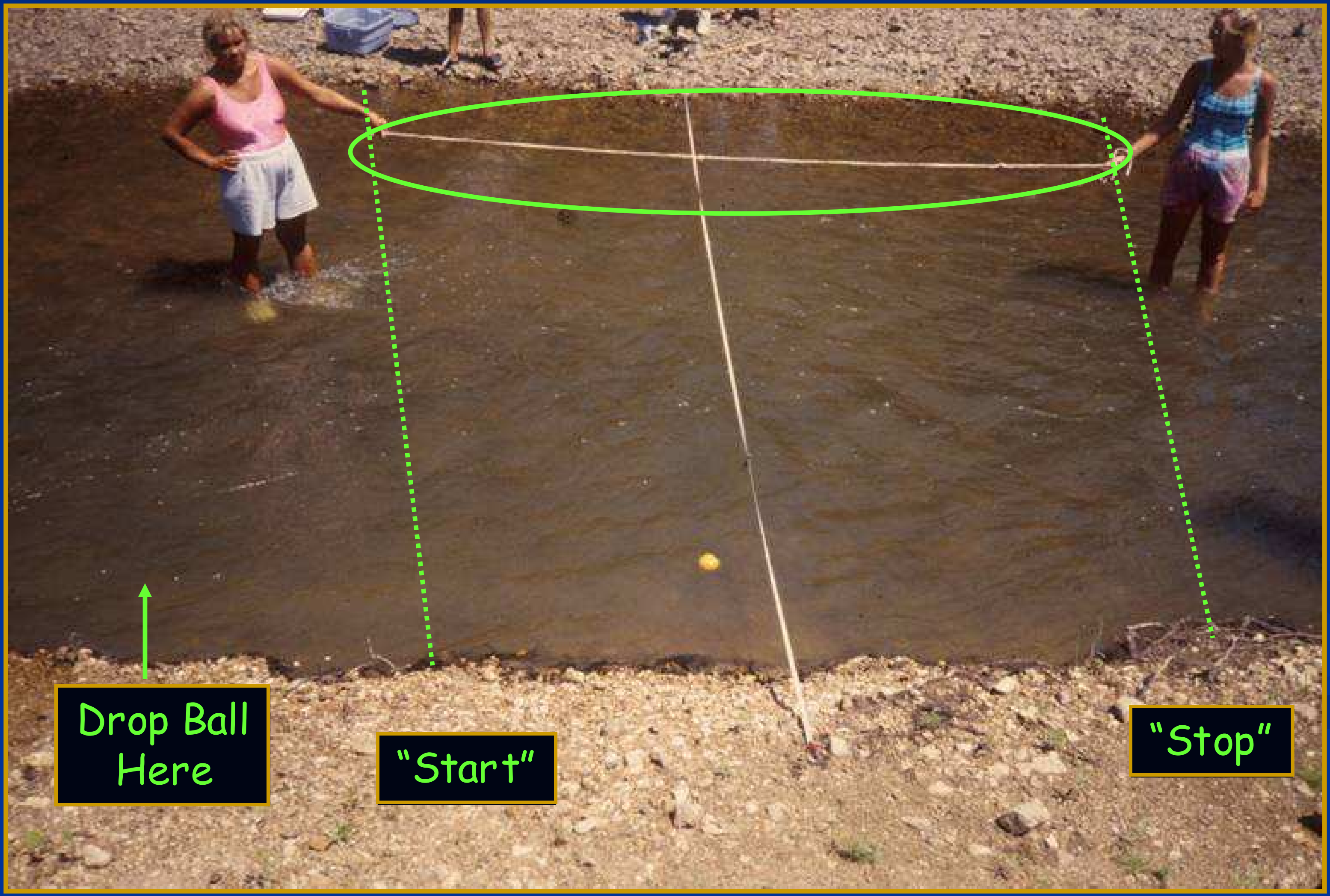


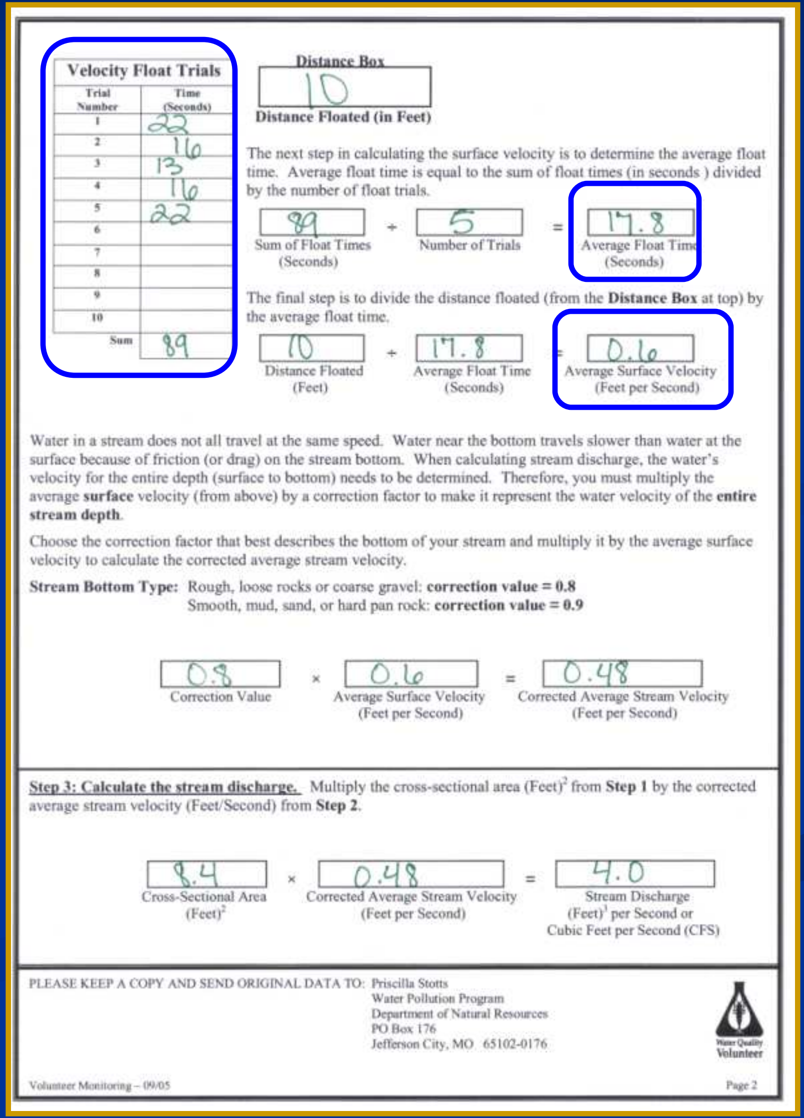
How to Measure Flow
Step 3 – Surface Velocity



How to Measure Flow

Stream Discharge Worksheet

- Velocity Float Trials
- Average Float Time
- Average Surface Velocity



Velocity Float Trials

Trial Number	Time (Seconds)
1	22
2	16
3	13
4	16
5	22
6	
7	
8	
9	
10	
Sum	89

Distance Box

10

Distance Floated (in Feet)

The next step in calculating the surface velocity is to determine the average float time. Average float time is equal to the sum of float times (in seconds) divided by the number of float trials.

89 ÷ 5 = 17.8

Sum of Float Times (Seconds) ÷ Number of Trials = Average Float Time (Seconds)

The final step is to divide the distance floated (from the **Distance Box** at top) by the average float time.

10 ÷ 17.8 = 0.6

Distance Floated (Feet) ÷ Average Float Time (Seconds) = Average Surface Velocity (Feet per Second)

Water in a stream does not all travel at the same speed. Water near the bottom travels slower than water at the surface because of friction (or drag) on the stream bottom. When calculating stream discharge, the water's velocity for the entire depth (surface to bottom) needs to be determined. Therefore, you must multiply the average **surface** velocity (from above) by a correction factor to make it represent the water velocity of the **entire stream depth**.

Choose the correction factor that best describes the bottom of your stream and multiply it by the average surface velocity to calculate the corrected average stream velocity.

Stream Bottom Type: Rough, loose rocks or coarse gravel: **correction value = 0.8**
Smooth, mud, sand, or hard pan rock: **correction value = 0.9**

0.8 × 0.6 = 0.48

Correction Value × Average Surface Velocity (Feet per Second) = Corrected Average Stream Velocity (Feet per Second)

Step 3: Calculate the stream discharge. Multiply the cross-sectional area $(Feet)^2$ from **Step 1** by the corrected average stream velocity (Feet/Second) from **Step 2**.

8.4 × 0.48 = 4.0

Cross-Sectional Area $(Feet)^2$ × Corrected Average Stream Velocity (Feet per Second) = Stream Discharge $(Feet)^3$ per Second or Cubic Feet per Second (CFS)

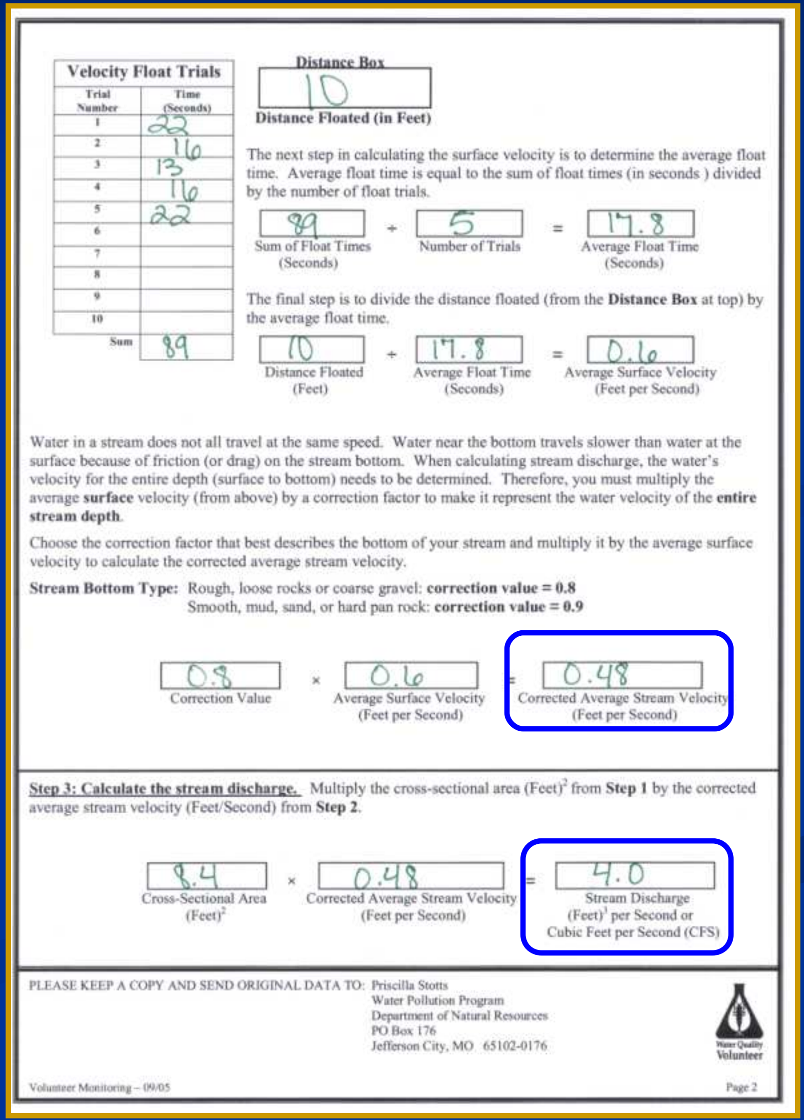
PLEASE KEEP A COPY AND SEND ORIGINAL DATA TO: Priscilla Stotts
Water Pollution Program
Department of Natural Resources
PO Box 176
Jefferson City, MO 65102-0176

Water Quality Volunteer

How to Measure Flow

Stream Discharge Worksheet

- Velocity Float Trials
- Average Float Time
- Average Surface Velocity
- Corrected Average Steam Velocity
- Stream Discharge



Velocity Float Trials	
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10 ÷ 17.8 = 0.6

Distance Floated (Feet) ÷ Average Float Time (Seconds) = Average Surface Velocity (Feet per Second)

Water in a stream does not all travel at the same speed. Water near the bottom travels slower than water at the surface because of friction (or drag) on the stream bottom. When calculating stream discharge, the water's velocity for the entire depth (surface to bottom) needs to be determined. Therefore, you must multiply the average **surface** velocity (from above) by a correction factor to make it represent the water velocity of the **entire stream depth**.

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Correction Value × Average Surface Velocity (Feet per Second) = Corrected Average Stream Velocity (Feet per Second)

Step 3: Calculate the stream discharge. Multiply the cross-sectional area $(Feet)^2$ from **Step 1** by the corrected average stream velocity (Feet/Second) from **Step 2**.

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Cross-Sectional Area $(Feet)^2$ × Corrected Average Stream Velocity (Feet per Second) = Stream Discharge $(Feet)^3$ per Second or Cubic Feet per Second (CFS)

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